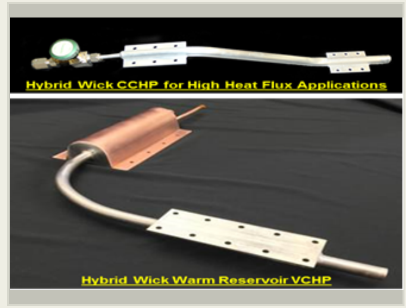
Hybrid Heat Pipes for High Heat Flux Applications, Phase II

Completed Technology Project (2015 - 2021)

Project Introduction

The thermal transport requirements for future spacecraft missions continue to increase, approaching several kilowatts. At the same time the heat acquisition areas have trended downward, thereby increasing the incident heat flux. Current incident heat flux for laser diode applications is on the order of 5-10W/cm2, although this is expected to increase towards 50W/cm2. This is a severe limitation for axial groove aluminum/ammonia constant conductance heat pipes (CCHPs). The maximum heat flux in a CCHP is set by the boiling limit, which typically start at 5 W/cm2 for axial grove wicks, and 20-30 W/cm2 for powder metal wicks. The innovation is to develop CCHPs with a hybrid wick, which has a sintered evaporator wick, and a conventional grooved adiabatic and condenser wick. These hybrid wicks can operate at higher heat fluxes, allowing the use of higher power laser diodes. They also allow the use of Variable Conductance Heat Pipes (VCHPs) in Lunar and Martian Landers and Rovers, which must operate at tilts up to 45°. Conventional aluminum/ammonia heat pipes can only operate with a 0.1 inch tilt, so they are unsuitable. Loop Heat Pipes can also operate with tilting, but they are two orders of magnitude more expensive. A hybrid grooved and sintered wick CCHP will allow operating at higher heat fluxes as compared to axial groove design and can also operate against gravity on the planetary surface, operate in space, carrying power over long distances, act as a thermosyphon on the planetary surface for Lunar and Martian landers and rovers, and demonstrate a higher transport capability than an all-sintered wick.



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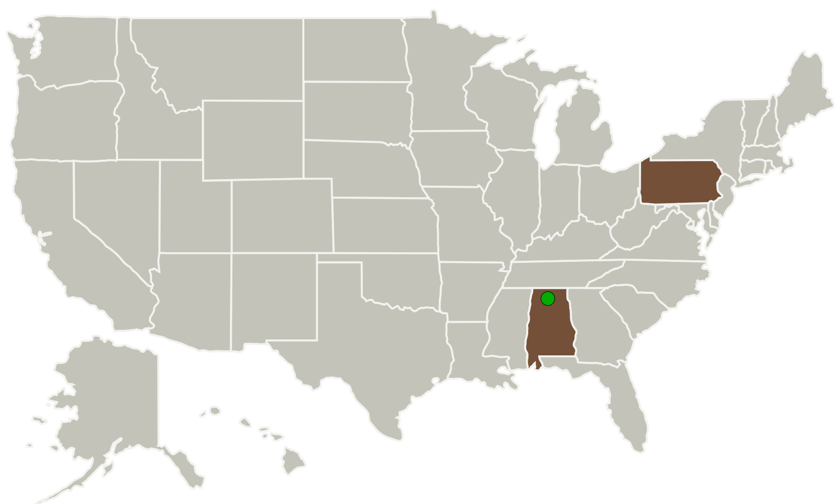
Anticipated Benefits

Hybrid wick CCHPs for high power electronics on spacecraft, and NASA landers and rovers is the immediate NASA application. Conventional grooved aluminum/ammonia CCHPs are heat flux limited and are only suitable for operation in space, or when they can be engineered to operate on a planetary surface in a gravity aided mode. The hybrid wicks developed on this program will remove this design constraint, and expand the design space to include higher heat flux operation and operation against gravity on future missions. Wicks developed on this program will enable the use of 3-D CCHPs for some NASA applications: with a hybrid wick, 3-D pipes can be fabricated and ground tested. Additional applications for the hybrid wick were identified, such as heat collecting and spreading for space based and planetary applications. Heat generating electronics are typically buried within an enclosure: the electronics will be mounted in various configurations on circuit cards and aluminum mounting planes. The goal is to accept and isothermalize the thermal load within the enclosure from the individual electronics components and transfer the energy to a location for heat. Strategically embedding heat pipes with hybrid wicks within these planes relevant to the high power components can increase the effective thermal conductivity by 2 to 4 times. These high conductivity plates are essential in the overall Thermal Management System for NASA electronics enclosures applications.The maximum allowable evaporator heat flux in a grooved pipe is relatively low, typically 10-15 W/cm^2. As spacecraft electronics increase in power and packing density, this can present a thermal control problem. Sintered wicks have much higher evaporator heat flux limits, typically four times higher than grooved wicks. The main non-NASA application will be for CCHPs that remove waste heat from high power components on commercial and military spacecraft. Several interested commercial customers in this technology development have been identified, for cooling of laser based components to high heat flux components on-board commercial satellites. Due to the intensive requirements on Military systems for electronics, there are also severe high heat flux cooling requirements. A hybrid wick CCHP with high heat flux capabilities would be highly beneficial. There are cost and mass penalties to competing technologies, such as Loop Heat Pipes and thermal spreaders.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Advanced Cooling Technologies, Inc.	Lead Organization	Industry	Lancaster, Pennsylvania
Marshall Space Flight Center(MSFC)	Supporting Organization	NASA Center	Huntsville, Alabama

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

Advanced Cooling Technologies, Inc.

Responsible Program:

Small Business Innovation Research/Small Business Tech Transfer

Project Management

Program Director:

Jason L Kessler

Program Manager:

Carlos Torrez

Project Managers:

Gwenevere L Jasper
Jeffery T Farmer

Principal Investigator:

Mohammed Ababneh

Small Business Innovation Research/Small Business Tech Transfer

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Primary U.S. Work Locations	
Alabama	Pennsylvania

Project Transitions

June 2015: Project Start

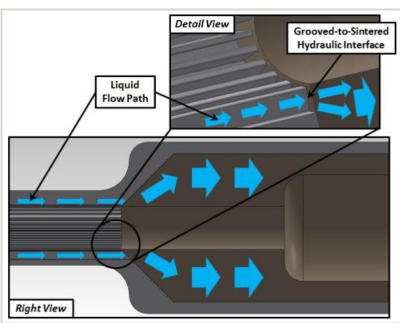
September 2021: Closed out

Closeout Documentation:
- Final Summary Chart PDF*(https://techport.nasa.gov/file/137772)*

September 2021: Closed out

Closeout Documentation:
- Final Summary Chart*(https://techport.nasa.gov/file/137773)*

Images



Briefing Chart
Hybrid Heat Pipes for High Heat Flux Applications Briefing Chart *(https://techport.nasa.gov/image/128320)*

Final Summary Chart Image
Hybrid Heat Pipes for High Heat Flux Applications, Phase II *(https://techport.nasa.gov/image/132880)*

Technology Maturity (TRL)

Start: **3**
Current: **5**
Estimated End: **5**

1 2 3 4 5 6 7 8 9

Applied Research | Development | Demo & Test

Target Destinations

The Sun, Earth, The Moon, Mars, Others Inside the Solar System, Outside the Solar System